Martian Polar Vortex Dynamics and the 2018 Global Dust Storm

Conference or Workshop Item

Martian polar vortex dynamics and the 2018 Global Dust Storm

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Introduction

Mars' winter atmosphere is characterized by a polar vortex of low temperatures around the winter pole, circumscribed by a strong westerly jet [e.g. 1]. These vortices are a key part of the atmospheric circulation and impact heavily on dust and volatile transport. They have a complex and asymmetrical (north/south) relationship with atmospheric dust loading [1]. Regional and global dust events have been shown to cause rapid vortex displacement [2,3] in the northern vortex, while the southern vortex appears more robust. This has implications for tracer transport through the zonal jets associated with the vortices [4]; a more coherent and low-latitude zonal jet should provide a more effective barrier against tracers entering the polar regions. The 2018 Mars Global Dust Storm (GDS) was observed through its lifecycle by the Mars Climate Sounder (MCS) instrument aboard the Mars Reconnaissance Orbiter [5]; using data assimilation [6] to integrate MCS retrievals [7] with the LMD-UK Mars Global Circulation Model (MGCM) [8] offers an opportunity to examine the effects of the GDS on the polar vortices.

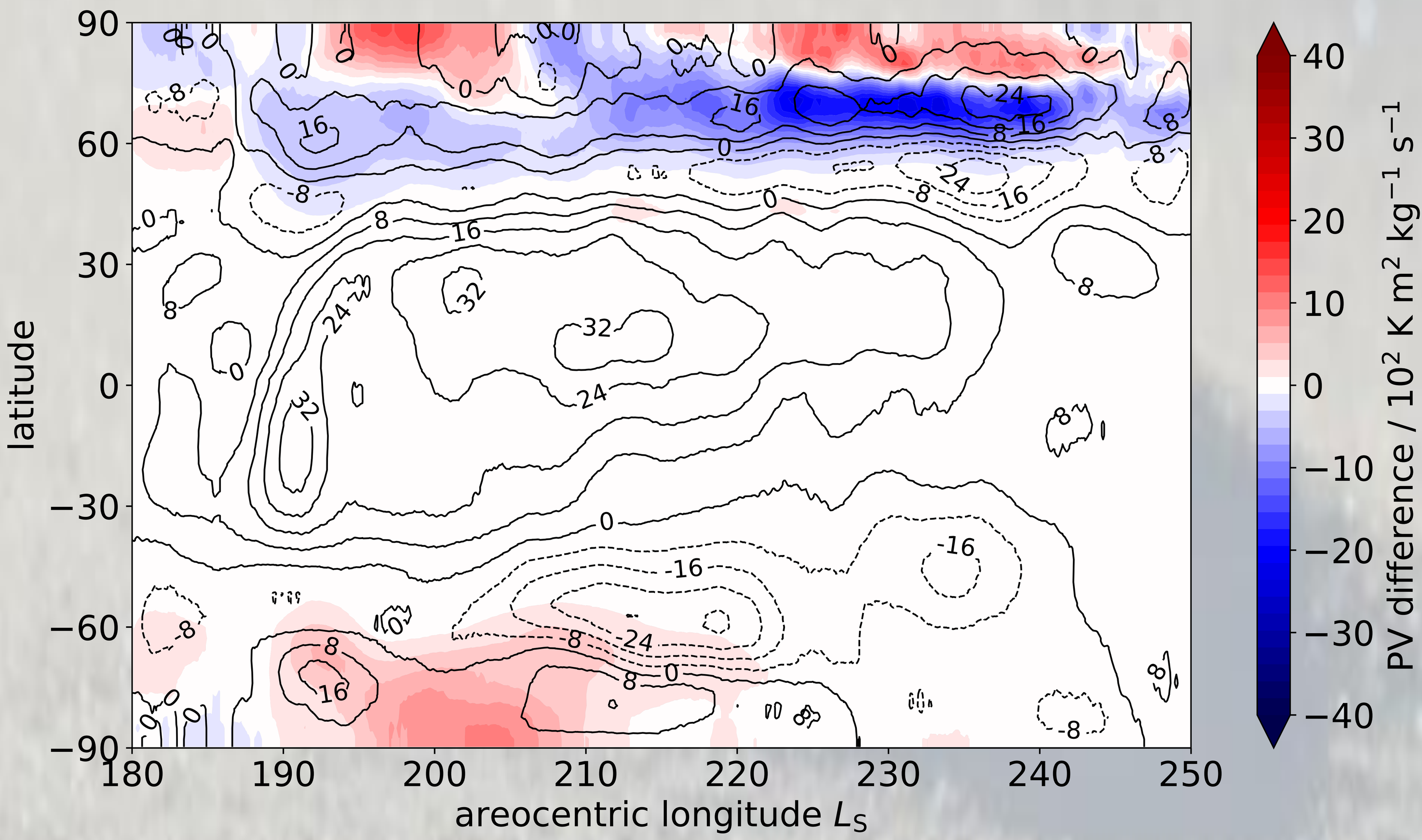

Fig. 2: difference between zonally-averaged PV (colours) and zonal wind speeds (contours) for MY 34 and MY 30 (MY 34 – MY 30), for the 300 K isentropic surface (PV) and for wind speeds between 20-30 km.

Temporal variation

- Fig. 2 shows the effect of the GDS throughout its lifespan on PV and zonal wind speeds
- At the northern pole, PV decreased at latitudes centred around 60 degrees and increased poleward of that, indicating a poleward shift of the polar vortex. The greatest effect was between L_S=220-240°, as the GDS decayed. There was a corresponding increase in zonal wind speeds at around 60° N
- At the southern pole, PV simply decreased at high latitudes as the polar vortex decay was accelerated by high southern dust loading and corresponding warming. Wind speeds around 60° S correspondingly decreased

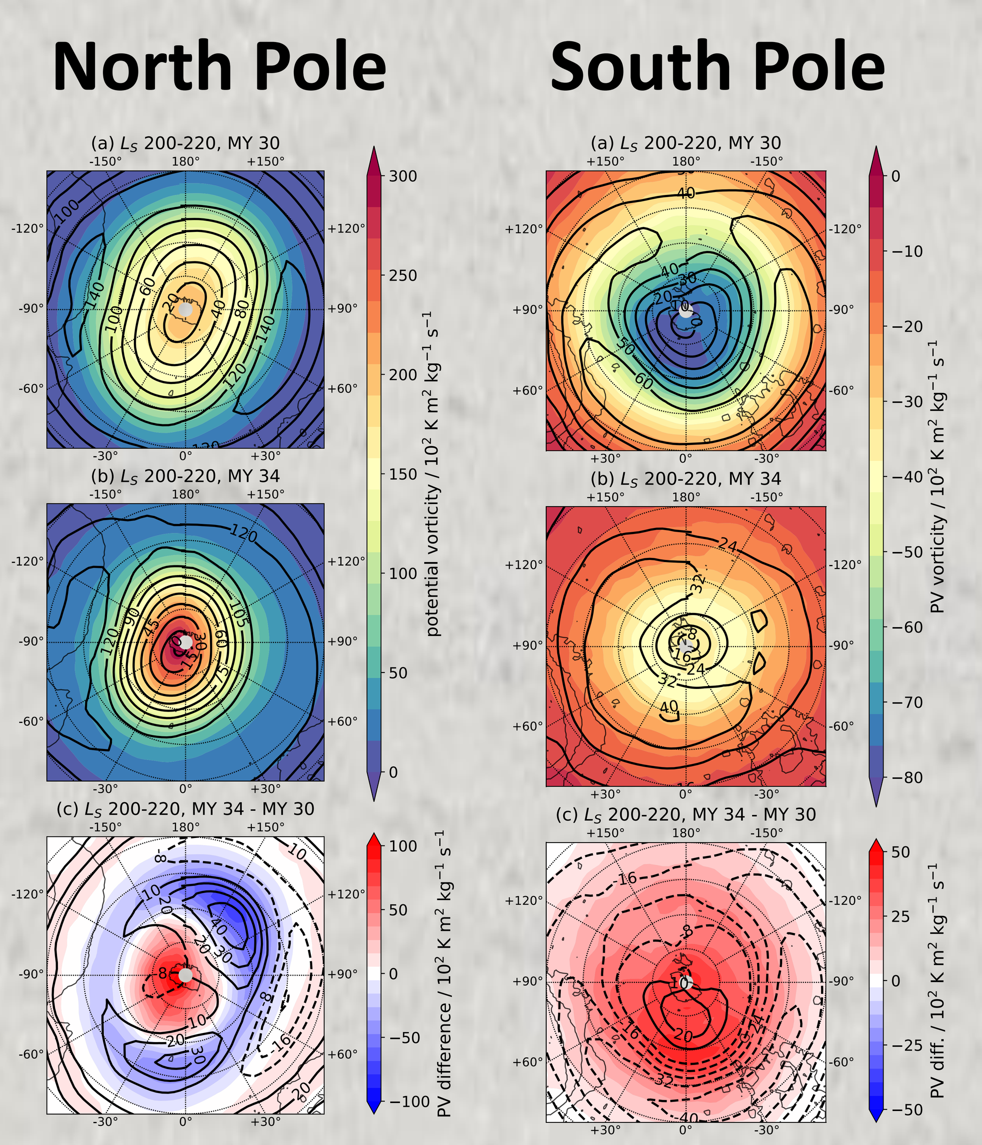

Fig. 3: As Fig. 1, but for PV at the 400 K isentropic surface and zonal winds between 30-40 km altitude.

Vertical variation

- Fig. 3 shows Fig. 1 but at higher altitudes: the 400 K isentropic surface for PV and zonal winds at 30-40 km
- In the north, PV decrease follows the lower level pattern but there is a more striking PV increase within 20° of the pole itself. This suggests a higher altitude polar vortex
- In the south, the results follow the lower level pattern, showing consistent decrease in PV and a narrow increase in wind speeds above the pole as the polar vortex's annular structure collapsed

Global dust storm effects

- Fig. 1 shows the impact of the GDS on the potential vorticity (PV) and zonal wind speeds at the 300 K isentropic surface and as averaged between 20-30 km, respectively
- In the north, the GDS reduced PV but in an asymmetrical fashion, with maxima in decreases at around 150 and 0 degrees longitude. The pattern of PV decrease indicates a poleward shift of the polar vortex
- Northern zonal wind speeds decreased at lower latitudes (50-60 degrees) and increased at higher latitudes (60-70 degrees), with maxima in increases tracking maxima in PV decreases. Again this indicates a poleward shift of the westerly jet core
- In the south, the highly asymmetric and already declining polar vortex showed a dramatic reduction, accelerating its decay
- Southern zonal wind speeds decreased at all latitudes except at the location of the former PV minimum centred at 30 degrees longitude, with residual high wind speeds at very high latitudes. This shows a remnant polar vortex remained at very high latitudes

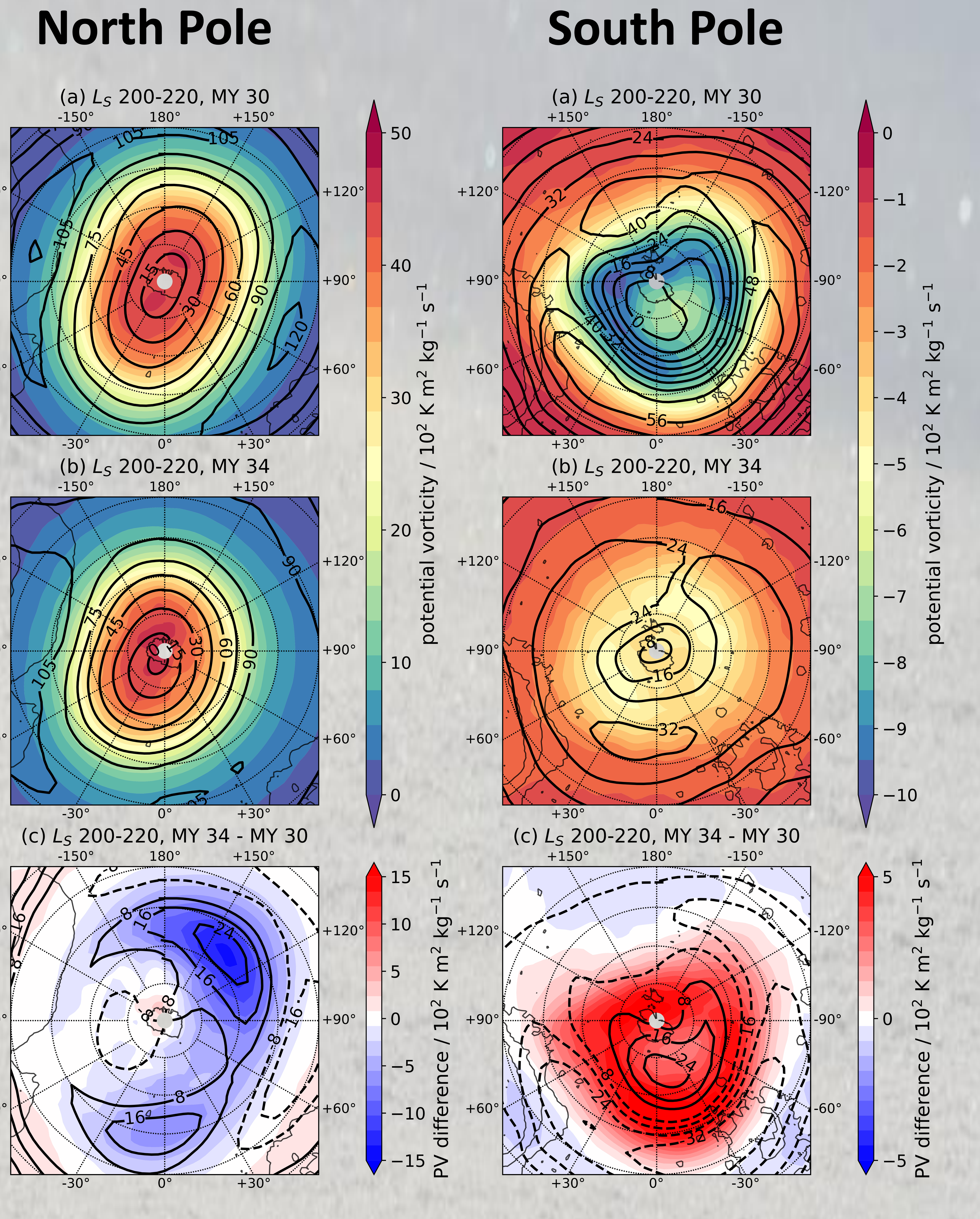

Fig. 1: Potential vorticity at the 300 K isentropic surface (PV) and zonal wind speeds averaged between 20-30 km for MY 30 and MY 34, and the difference between them, for the north (left) and south (right) poles. Each circular line represents latitudes at 10 degree intervals, with the outermost circle being at 50 degrees. For the difference plots, dashed contour lines represent negative values.

References

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Summary

- The 2018 GDS was an equinoctial event, beginning as the northern polar vortex was growing and the southern polar vortex was decaying
- The GDS appeared to shift the northern polar vortex poleward; the lack of high dust loading at high northern latitudes indicates this was due to the dynamical effects of an enhanced Hadley circulation
- The GDS drastically accelerated the seasonal decay of the southern polar vortex; this was likely due to the enhanced diabatic heating from the high southern hemisphere dust loading destroying the equator-pole temperature gradient
- The poleward shift in the highest westerly wind speeds at both poles suggests that equinoctial GDS events could allow greater tracer transport to high latitudes

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